

## WE CLAIM:

1. An apparatus comprising a plurality of optical amplification media segments which are concatenated in series wherein subsequent to each optical amplification media segment a respective one or more wavelengths in a respective wavelength range is dropped so as to exploit a gain versus optical amplification media physical length characteristic.  
5
2. An apparatus according to claim 1 wherein each amplification media segment comprises a fiber amplification media segment.  
10
3. An apparatus according to claim 2, wherein each particular subsequent concatenated fiber amplification media segment adds an additional physical length of fiber amplification media to the apparatus so as to exploit the gain  
15 versus fiber amplification media physical length characteristic wherein each particular additional physical length of fiber amplification media is chosen so that an overall length of fiber amplification media, including the particular fiber amplification media segment and all preceding physical lengths  
20 of fiber amplification media, when supplied with pump laser energy, provide a respective gain response over the respective wavelength range containing the respective one or more wavelengths to be dropped after the particular segment.
4. An apparatus according to claim 1, adapted to perform  
25 amplification in an overall wavelength range comprising at least 1523 nm to 1617 nm.
5. An apparatus according to claim 1, wherein the wavelengths are located on a standard telecommunications grid with a wavelength spacing of substantially 20 nm.

6. An apparatus according to claim 5, wherein the wavelength ranges are centred at 1550 nm, 1570 nm, 1590 nm, and 1610 nm.

7. An apparatus according to claim 5, wherein the wavelength ranges are centred at 1530 nm, 1550 nm, 1570 nm, 1590 nm, and 1610 nm.

8. An apparatus according to claim 5, wherein the wavelength ranges are  $1550 \pm 6.5$  nm,  $1570 \pm 6.5$  nm,  $1590 \pm 6.5$  nm and  $1610 \pm 6.5$  nm.

10 9. An apparatus according to claim 8 wherein the wavelength  $1550 \pm 6.5$  nm is dropped after a first segment of the plurality of amplification media segments, the wavelengths  $1570 \pm 6.5$  nm and  $1590 \pm 6.5$  nm are dropped after a second segment of the plurality of amplification media segments, and  
15 the wavelength  $1610 \pm 6.5$  nm is dropped after a third of the plurality of amplification media segments.

10. An apparatus according to claim 5, wherein the wavelength ranges are  $1530 \pm 6.5$  nm,  $1550 \pm 6.5$  nm,  $1570 \pm 6.5$  nm,  $1590 \pm 6.5$  nm and  $1610 \pm 6.5$  nm.

20 11. An apparatus according to claim 4, wherein the apparatus is used to amplify a plurality of dense wavelength division multiplexed (DWDM) wavelengths in the range 1523 nm to 1670 nm, which are located on a standard telecommunications grid with a frequency spacing of substantially 25 GHz, 50 GHz,  
25 100 GHz, or 200 GHz.

12. An apparatus according to claim 2, wherein the plurality of fiber amplification media segments are collectively supplied with pump laser energy using at least one pump laser.

13. An apparatus according to claim 12, further comprising a plurality of couplers wherein each of the plurality of fiber amplification media segments is supplied with a required level of pump laser energy from the at least 5 one pump laser using at least one of the plurality of couplers to make a gain response for all of the wavelength channels approximately equal.

14. An apparatus according to claim 2, wherein the plurality of fiber amplification media segments are 10 collectively supplied with pump laser energy using only one pump laser.

15. An apparatus according to claim 14, further comprising a plurality of couplers wherein each of the plurality of fiber amplification media segments is supplied 15 with a required level of pump laser energy from the one pump laser using at least one of the plurality of couplers.

16. An apparatus according to claim 2, wherein the plurality of fiber amplification media segments are lengths of erbium doped fiber (EDF).

20 17. An apparatus according to claim 1, further comprising at least one ASE (amplified spontaneous emission) noise suppression filter (NSF) filtering at least one of the wavelength ranges.

18. An apparatus according to claim 1, wherein after a 25 last of the plurality of amplification media segments, the one or more wavelengths to be dropped are passed through an ASE NSF (noise suppression filter).

19. An apparatus according to claim 18 wherein the NSF has a transmission characteristic for a wavelength range which 30 flattens the gain characteristic of the amplification media over the wavelength range.

20. An apparatus according to claim 19 wherein the wavelength range of the NSF is about 1603 nm to 1617 nm.
21. An apparatus according to claim 1, further comprising a plurality of optical fiber taps and a plurality of photodetectors used in combinations at an input and an output of the apparatus for power monitoring a multi-wavelength optical input and a multi-wavelength optical output.
22. An apparatus according to claim 2, further comprising a plurality of optical isolators, wherein each of the plurality of fiber amplification media segments is located in series with a corresponding individual optical isolator of the plurality of optical isolators.
23. An apparatus according to claim 1 further comprising, for each pair of adjacent amplification media segments comprising a preceding segment and a subsequent segment, a respective multi-port add-drop multiplexer between the preceding segment and the subsequent segment, each multi-port add-drop multiplexer being adapted to receive an amplified signal from the preceding segment, drop a wavelength to be dropped after the preceding segment, and passing a remaining signal on towards the subsequent segment.
24. An apparatus according to claim 23 further comprising a multi-port optical multiplexer connected to combine the dropped wavelengths.
- 25 25 An apparatus according to claim 23 wherein each multi-port add-drop multiplexer is a four port add-drop multiplexer.
26. An apparatus according to claim 25 wherein each four port add-drop multiplexer comprises:

a first port for inputting a first signal which is an output of the preceding amplification media segment;

5 a second port for outputting a second signal which is passed to the subsequent amplification media segment for further amplification;

a third port for outputting a third signal;

10 a fourth port for inputting a fourth signal from a third port of a subsequent add-drop multiplexer or in the case of the last add drop multiplexer, the fourth signal being an output of the last amplification segment;

15 wherein each add-drop multiplexer passes the at least one wavelength to be dropped transmissively between the first port and the third port, reflects other wavelengths from the first port to the second port for further amplification, and reflects wavelengths from the fourth port to the third port for combination with the dropped wavelength.

27. An apparatus according to claim 26 wherein the wavelength  $1550 \pm 6.5$  nm is dropped by a first four port add-drop multiplexer after a first segment of the plurality of 20 amplification media segments, the wavelengths  $1570 \pm 6.5$  nm and  $1590 \pm 6.5$  nm are dropped after a second segment of the plurality of amplification media segments by second and third four port add-drop multiplexers, and the wavelength  $1610 \pm 6.5$  nm is dropped after a third of the plurality of amplification 25 media segments.

28. An apparatus for amplifying a multi-wavelength optical input, the apparatus comprising:

a plurality of erbium doped fiber lengths;

30 a plurality of multi-port optical add-drop multiplexers;

a plurality of optical power splitters;  
a plurality of wavelength couplers;  
a N:1 optical multiplexer; and  
at least one pump laser for supplying pump laser  
5 energy,

wherein the multi-wavelength optical input is amplified by a first amplification stage comprising a first wavelength coupler, a first length of erbium doped fiber and passed to a first multi-port optical add-drop multiplexer,

10 the first wavelength coupler combines the multi-wavelength optical input with a first pump laser energy supplied by the at least one pump laser,

15 the first length of erbium doped fiber amplifies the multi-wavelength optical input and inputs an amplified multi-wavelength optical input to a first input port of the first multi-port optical add-drop multiplexer,

20 wherein an amplified first wavelength of the amplified multi-wavelength optical input is dropped to a first output port of the first multi-port optical add-drop multiplexer, the amplified first wavelength being supplied to a first input port of a N:1 optical multiplexer and remaining amplified wavelengths comprising the amplified multi-wavelength optical input minus the amplified first wavelength are passed to a second amplification stage via a second output port of the  
25 first multi-port optical add-drop multiplexer,

the remaining amplified wavelengths are further amplified by a second amplification stage comprising a second wavelength coupler, a second length of erbium doped fiber and a second multi-port optical add-drop multiplexer,

the second wavelength coupler combines the remaining amplified wavelengths with a second pump laser energy supplied by the at least one pump laser,

the second length of erbium doped fiber further  
5 amplifies the remaining amplified wavelengths and inputs remaining further amplified wavelengths to a first input port of the second multi-port optical add-drop multiplexer,

wherein an amplified second wavelength of the remaining further amplified wavelengths is dropped to a first  
10 output port of the second multi-port optical add-drop multiplexer, the amplified second wavelength being supplied to a second input port of the N:1 optical multiplexer and remaining twice amplified wavelengths comprising the remaining further amplified wavelengths minus the amplified second  
15 wavelength are passed to a third multi-port optical add-drop multiplexer via a second output port of the second multi-port optical add-drop multiplexer,

the remaining twice amplified wavelengths are supplied to a first input port of the third multi-port optical  
20 add-drop multiplexer, wherein an amplified third wavelength of the remaining twice amplified wavelengths is dropped to a first output port of the third multi-port optical add-drop multiplexer, the amplified third wavelength being supplied to a third input port of the N:1 optical multiplexer and a last  
25 remaining twice amplified wavelength consisting of a fourth wavelength is passed to a third amplification stage via a second output port of the third multi-port optical add-drop multiplexer,

the fourth wavelength is amplified by the third  
30 amplification stage comprising a third wavelength coupler, a third length of erbium doped fiber and a fourth multi-port optical add-drop multiplexer,

the third wavelength coupler combines the fourth wavelength with a third pump laser energy supplied by the at least one pump laser,

5 the third length of erbium doped fiber amplifies the fourth wavelength and inputs an amplified fourth wavelength to a first input port of the fourth multi-port optical add-drop multiplexer,

10 wherein the amplified fourth wavelength is supplied by a first output of the fourth multi-port optical add-drop multiplexer to a fourth input port of the N:1 optical multiplexer,

15 the amplified first, amplified second, amplified third, and amplified fourth wavelengths are input to and combined by the N:1 optical multiplexer to generate a multi-wavelength optical output which has a substantially flat gain; and

20 the at least one pump laser and the plurality of power splitters generate the first, second and third pump laser energies for the first, second and third erbium doped fiber lengths, respectively.

29. An apparatus according to claim 28, wherein the plurality of multi-port optical add-drop multiplexers have at least 3 ports.

30. An apparatus according to claim 28 further comprising 25 a noise suppression filter after the third erbium doped fiber length an output of which is supplied to the N:1 optical multiplexer.

31. An apparatus according to claim 30 wherein the wavelengths occupy wavelength ranges centred at 1550 nm, 1570 30 nm, 1590 nm, and 1610 nm.

32. An apparatus according to claim 30, wherein the wavelength ranges are  $1550 \pm 6.5$  nm,  $1570 \pm 6.5$  nm,  $1590 \pm 6.5$  nm and  $1610 \pm 6.5$  nm.

33. An apparatus for amplifying a multi-wavelength optical input, the apparatus comprising:

a plurality of erbium doped fiber lengths;

a plurality of multi-port optical add-drop multiplexers;

a plurality of optical power splitters;

10 a plurality of wavelength couplers;

at least one NSF; and

at least one pump laser for supplying pump laser energy,

wherein the multi-wavelength optical input is  
15 amplified by a first amplification stage comprising a first wavelength coupler, a first length of erbium doped fiber and a first multi-port optical add-drop multiplexer,

the first wavelength coupler combines the multi-wavelength optical input with a first pump laser energy  
20 supplied by the at least one pump laser,

the first length of erbium doped fiber amplifies the multi-wavelength optical input and inputs an amplified multi-wavelength optical input to a first input port of the first multi-port optical add-drop multiplexer,

25 wherein an amplified first wavelength of the amplified multi-wavelength optical input is combined with a first amplified multi-wavelength optical signal comprising amplified second, amplified third and amplified fourth

wavelengths output from a second amplification stage and input at a second input port of the first multi-port optical add-drop multiplexer, a combined amplified multi-wavelength optical signal of the amplified first, the amplified second, the  
5 amplified third and the amplified fourth wavelengths output at a first output port of the first multi-port optical add-drop multiplexer and remaining amplified wavelengths comprising the amplified multi-wavelength optical input minus the amplified first wavelength are passed to the second amplification stage  
10 via a second output port of the first multi-port optical add-drop multiplexer,

the remaining amplified wavelengths are further amplified by the second amplification stage comprising a second wavelength coupler, a second length of erbium doped fiber and a  
15 second multi-port optical add-drop multiplexer,

the second wavelength coupler combines the remaining amplified wavelengths with a second pump laser energy supplied by the at least one pump laser,

the second length of erbium doped fiber further  
20 amplifies the remaining amplified wavelengths and supplies remaining further amplified wavelengths to a first input port of the second multi-port optical add-drop multiplexer,

wherein an amplified second wavelength of the remaining further amplified wavelengths is combined with a  
25 second amplified multi-wavelength optical signal comprising the amplified third and the amplified fourth wavelengths output from a third multi-port optical add-drop multiplexer and input at a second input port of the second multi-port optical add-drop multiplexer, the first amplified multi-wavelength optical signal comprising the amplified second, the amplified third and the amplified fourth wavelengths output at a first output port of the second multi-port optical add-drop multiplexer and

remaining twice amplified wavelengths comprising the remaining further amplified wavelengths minus the amplified second wavelength are passed through a second output port of the second multi-port optical add-drop multiplexer to a third  
5 multi-port optical add-drop multiplexer,

the remaining twice amplified wavelengths are supplied to a first input port of the third multi-port optical add-drop multiplexer, wherein an amplified third wavelength of the remaining twice amplified wavelengths is combined with the  
10 amplified fourth wavelength output from the third amplification stage and input at a second input port of the third multi-port optical add-drop multiplexer, the second amplified multi-wavelength optical signal comprising the amplified third and the amplified fourth wavelengths output at a first output port  
15 of the third multi-port optical add-drop multiplexer and a last remaining twice amplified wavelength consisting of a fourth wavelength is passed to a third amplification stage via a second output port of the third multi-port optical add-drop multiplexer,

20 the fourth wavelength is amplified by the third amplification stage comprising a third wavelength coupler, a third length of erbium doped fiber and an ASE NSF,

25 the third wavelength coupler combines the fourth wavelength with a third pump laser energy supplied by the at least one pump laser,

the third length of erbium doped fiber amplifies the fourth wavelength and inputs the amplified fourth wavelength to an input of the ASE NSF and the amplified fourth wavelength output from the noise suppression filter is supplied to the  
30 second input port of the third multi-port optical add-drop multiplexer,

the combined amplified multi-wavelength optical signal of the amplified first, the amplified second, the amplified third and the amplified fourth wavelengths output from the first output port of the first multi-port optical add-  
5 drop multiplexer is a multi-wavelength optical output which has a substantially flat gain; and

the at least one pump laser and the plurality of power splitters generate the first, second and third pump laser energies for the first, second and third erbium doped fiber  
10 lengths, respectively.

34. An apparatus according to claim 33, wherein the NSF is a fused-fiber device or a thin film device.

35. An apparatus according to claim 33, wherein the plurality of multi-port optical add-drop multiplexers have at  
15 least 4 ports, a 4<sup>th</sup> port being the add port.

36. An apparatus according to claim 33, wherein the wavelengths occupy wavelength ranges centred at 1550 nm, 1570 nm, 1590 nm, and 1610 nm.

37. An apparatus according to claim 33, wherein the  
20 wavelength ranges are 1550 ± 6.5 nm, 1570 ± 6.5 nm, 1590 ± 6.5 nm and 1610 ± 6.5 nm.